McMASTER

PREPARATION OF 1.3 KG OF IMMOBILIZED

R. ARRHIZUS FOR BIOMASS ADSORPTION

FINAL REPORT

FOR

ENERGY, MINES AND RESOURCES CANADA

BY

DEPARTMENT OF CHEMICAL ENGINEERING
MCMASTER UNIVERSITY
HAMILTON, ONTARIO

JANUARY 1989

Engineering

89-04492/

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Work on this project was conducted under the auspices of the Canada Centre for Mineral and Energy Technology, Energy Mines and Resources Canada.

Contract File Number: 23440-8-9069/01-SS

Scientific Authority: Dr. R.G.L. McReady
Head, CANMET Biotechnology Section

MICROMEDIA

16 pp

JANUARY 1989

ABSTRACT

Immobilized R. arrhizus biomass was prepared using proprietary technology developed at McMaster University. The uranium adsorption characteristics of the biomass were determined.

RÉSUMÉ

Une biomasse de type R. arrhizus a été immobilisé selon une technique brevetée mise au point à l'Université McMaster. Les caractéristiques d'adsorption de l'uranium de cette biomasse ont été établies.

1. IMMOBILIZED BIOMASS PRODUCTION

1.1 INTRODUCTION

The purpose of this project was to prepare 1.3 kg of immobilized R. arrhizus biomass for uranium adsorption studies. The biomass was grown and immobilized using proprietary technology developed at McMaster University. Tests were also carried out to characterize the adsorptive properties of the biomass.

1.1 BIOMASS GROWTH

The R. arrhizus biomass was produced by fermentation in a glucose medium. Sterile procedures were used to insure production of a pure strain of R. arrhizus. The fermentations were carried out in a bench top fermentor with duplicate 14 L glass fermentation vessels. The fermentor was equipped with pH and temperature controllers, mechanical agitators, and sterile air supply systems. The fermentations were carried out at a temperature of 28 ^{o}C with an air flow rate of 7 L/min. The cultures showed first signs of growth after 24 hours with thick clumps of biomass observable after 36 hours. The biomass was harvested within 48 hours.

Upon completion of the fermentation, the contents of the fermentor vessels was filtered through nylon mesh filter bags to separate the R. arrhizus from the fermentation broth. The recovered biomass was then washed thoroughly with tap water until the wash water ran clear and colorless. Excess water was removed

by squeezing the biomass in the filter bags. The biomass was broken up into smaller pieces, spread on metal trays, and covered with cheesecloth. The biomass was then autoclaved for 30 minutes at 120 ^{o}C and 105 kPa. The sterilized biomass was squeezed again to remove any condensed steam and broken into smaller particles. The biomass was then placed into metal sieves, covered with cheesecloth and lyophilized at -50 ^{o}C for two days in a freeze drier. The biomass was sieved to separate the 16-20 mesh size fraction for immobilization. The remaining fines were collected and used for determination of uptake capacity. Twelve batches of biomass were produced using this procedure.

1.2 BIOMASS IMMOBILIZATION

The immobilization of the R. arrhizus biomass was carried out using the proprietary process developed at McMaster University, and 1.3 kg of immobilized biomass was produced.

2. BIOMASS PROPERTIES

2.1 URANIUM UPTAKE CAPACITY OF RAW BIOMASS

The uranium uptake capacity of the raw, uncoated biomass was tested by contacting samples of raw biomass from each batch with uranyl nitrate solution. Weighed biomass samples were placed into closed flasks with 100 mL of a 500 mg/L uranyl nitrate solution. The flasks were agitated on an orbital shaker for 24 hours. The solutions were then filtered to separate the biomass and the filtrate was analyzed for uranium concentration by ICP. The uranium uptake was calculated by mass balance. Table 1 gives the results of the uptake capacity tests.

The raw biomass appears to exhibit uptake capacity similar to that observed in the past with similar biomass.

2.2 URANIUM UPTAKE CAPACITY OF IMMOBILIZED BIOMASS

The uranium uptake capacity of the immobilized biomass was tested by contacting samples of immobilized biomass from three batches with processed Denison Mines bioleach solution. Weighed biomass samples were placed into closed flasks with 100 mL bioleach solution. The flasks were agitated on an orbital shaker for 23 days. The solutions were then filtered to separate the biomass and the filtrate was analyzed for uranium concentration by delayed neutron counting. The uranium uptake was calculated by mass balance. Table 2 gives the results of the uptake capacity tests. Figure 1 shows the adsorption isotherms for the three batches.

TABLE 1: URANIUM UPTAKE CAPACITY OF RAW BIOMASS

BATCH NO.	EQUILIBRIUM URANIUM CONCENTRATION (mg/L)	URANIUM UPTAKE (mg/g)
1	411.6	175.1
2	400.4	199.5
3	370.4	253.8
4	383.9	229.3
5	412.7	173.0
6	384.1	223.5
7	403.0	190.6
8	399.2	196.9
9	411.1	169.8
10	434.4	129.1
11	409.5	179.3
12	396.1	205.8
	AVERAGE UPTAKE:	193.8

TABLE 2: URANIUM UPTAKE CAPACITY OF IMMOBILIZED BIOMASS

BIOMASS BATCH	U CONC. (mg/l)	U UPTAKE (mg/g)
Spherical	226.0	189.9
	194.6	180.3
	131.4	153.7
	34.6	124.8
A	232.0	177.6
	202.0	167.0
	135.6	150.4
	44.4	119.7
B	220.5	201.1
	186.6	191.8
	107.4	175.1
	27.5	128.6

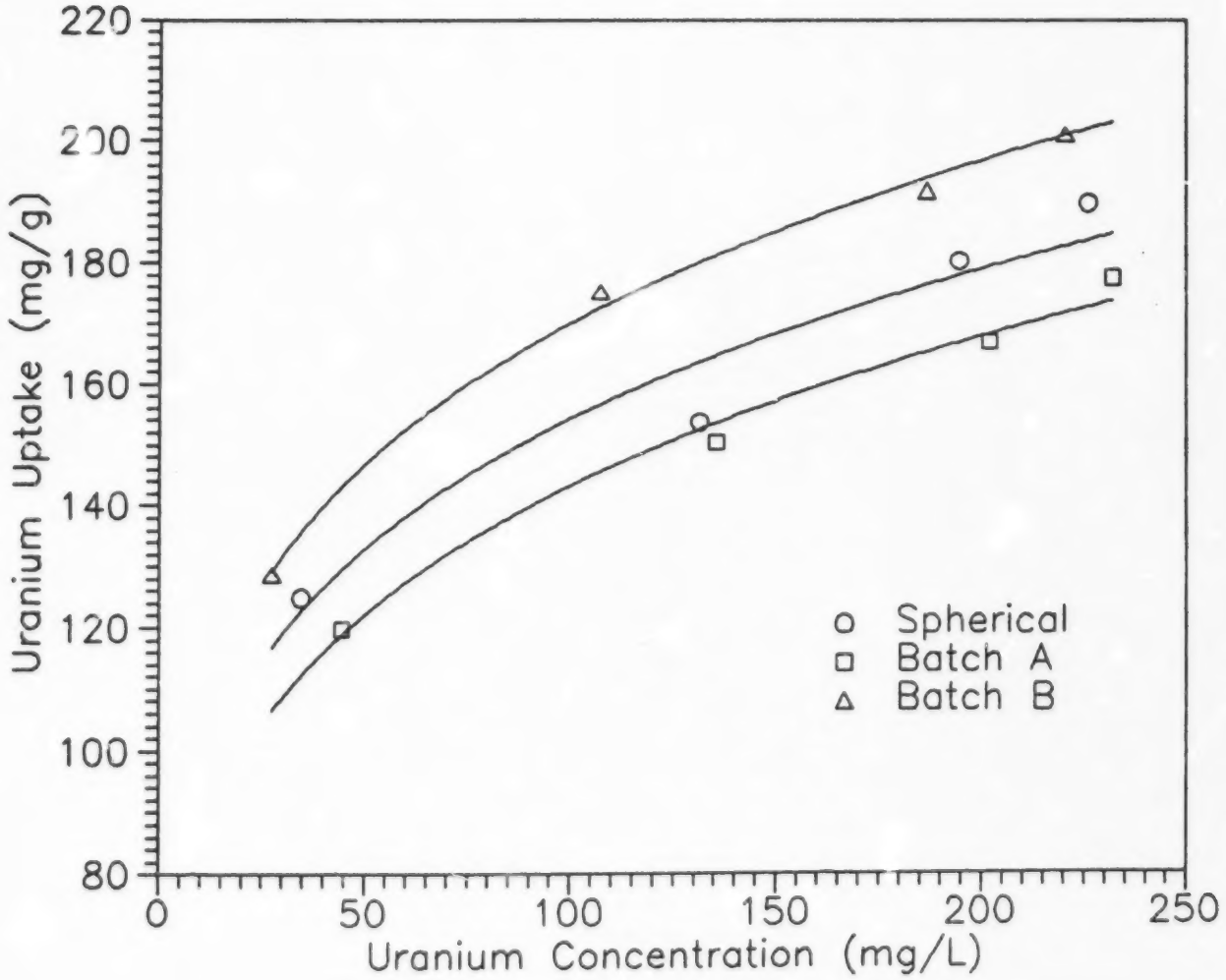

Figure 1 Uranium Uptake by Immobilized Biomass

The bioleach solution was processed by adjusting the pH to 4.0 and allowing the resulting precipitate to settle. The supernatant solution was filtered and used for testing the adsorption characteristics of the immobilized biomass. The processed bioleach solution was found to have a uranium concentration of 286 mg/L.

Three separate batches of immobilized biomass were tested for uranium uptake. One batch was produced from biomass grown as relatively spherical particles of uniform size. The other two batches were produced by the normal process of grinding and screening particles of random size and shape to produce a relatively uniform size fraction. These two batches were labelled Batch A and Batch B.

The uptake capacity of the three batches is similar. Batch B appears to exhibit slightly greater uptake than the spherical batch which in turn showed slightly greater uptake than Batch A. The uptake capacity appears to be greater than previously experienced with bioleach solutions. This is probably due to the characteristics of this particular bioleach solution since the uptake capacity of the raw biomass appears to be consistent with previous experience.

The Freundlich adsorption equation was fitted to the adsorption data for the three batches. The resulting adsorption curves are plotted in Figure 1. The following are the adsorption equations for each batch:

$$\text{Spherical:} \quad q = 57.2C^{0.22}$$

Batch A: $q = 49.6C^{0.23}$

Batch B: $q = 63.9C^{0.21}$

where

q = uranium uptake, mg/g,

C = equilibrium liquid phase uranium concentration, mg/L.

2.3 KINETICS OF URANIUM ADSORPTION

The kinetics of uranium uptake of the immobilized biomass from processed bioleach solution was tested using a Carberry type reactor. A measured quantity of immobilized biomass was placed in the rotating cage of the reactor which was filled with a measured quantity of processed bioleach solution. An equal mix of spherical, Batch A, and Batch B was used. Small samples were periodically withdrawn from the reactor and analyzed for uranium by delayed neutron counting. The results of the kinetics test are given on Table 3 and are shown graphically on Figure 2 and Figure 3. The curves fitting the kinetics data were hand drawn to show the trend of the data.

The kinetics of the uranium uptake appear to be consistent with previous experience with similar immobilized biomass. The system appears to essentially reach equilibrium in approximately one day, although a slight increase in uptake continued after that time.

TABLE 3: KINETICS OF URANIUM UPTAKE BY IMMOBILIZED BIOMASS

TIME (h)	U CONC. (mg/l)	U UPTAKE (mg/g)
0	286.0	0.0
0.017	272.0	5.8
0.083	236.0	20.7
0.417	212.0	30.7
0.583	191.6	39.2
0.750	173.6	46.6
1.000	181.6	43.3
1.250	151.8	55.7
1.500	138.4	61.2
1.750	132.8	63.6
3.750	97.4	78.3
5.750	77.8	86.4
9.083	65.0	91.7
11.333	57.8	94.7
21.750	43.4	100.7
29.750	41.4	101.5
45.750	36.4	103.6
53.750	34.2	104.5
69.750	30.6	106.0
78.417	29.4	106.5
94.750	30.6	106.0
118.833	30.4	106.1
142.750	28.2	107.0
166.750	26.4	107.7
172.250	24.6	108.5

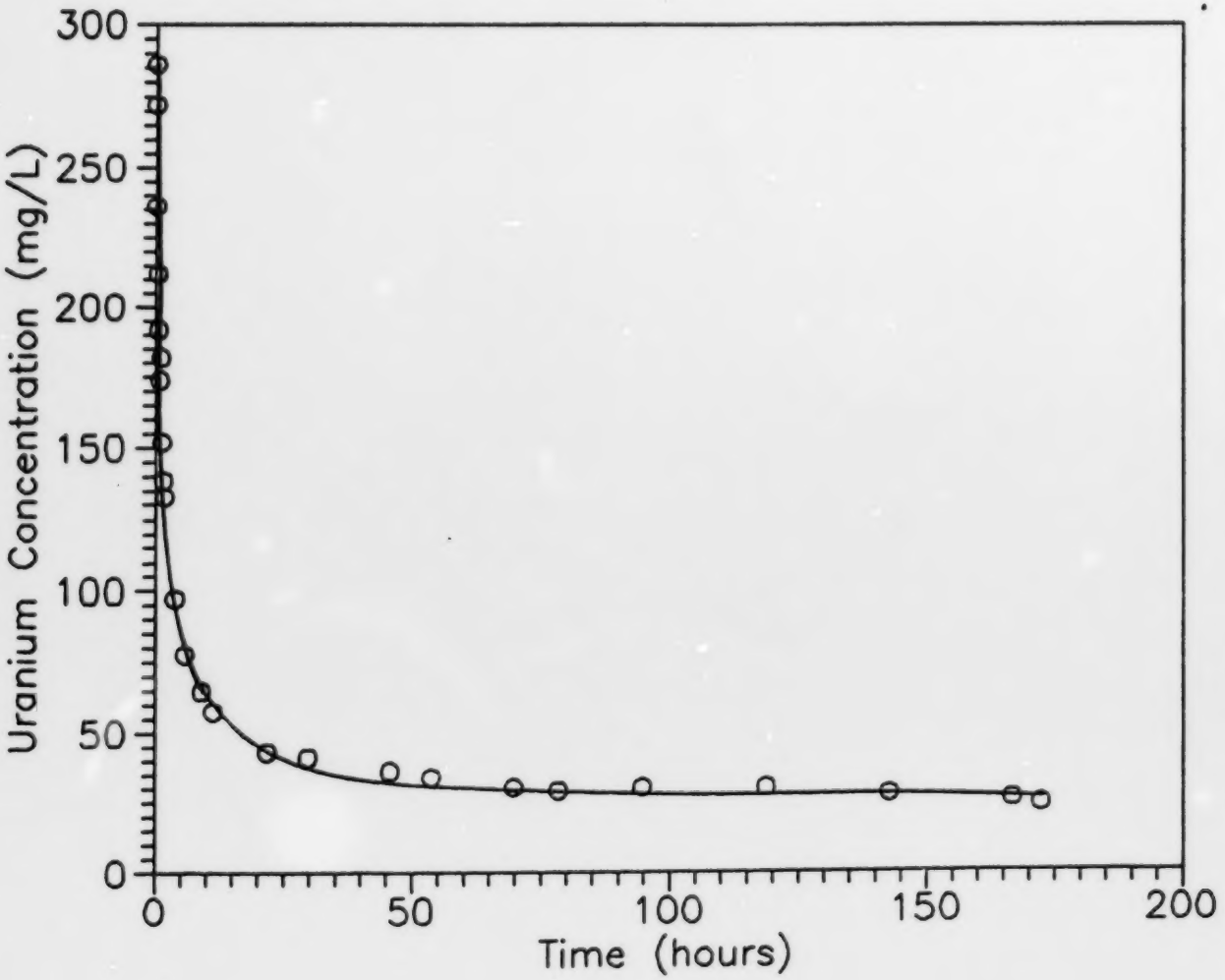

Figure 2 Kinetics of Uranium Uptake on Immobilized Biomass

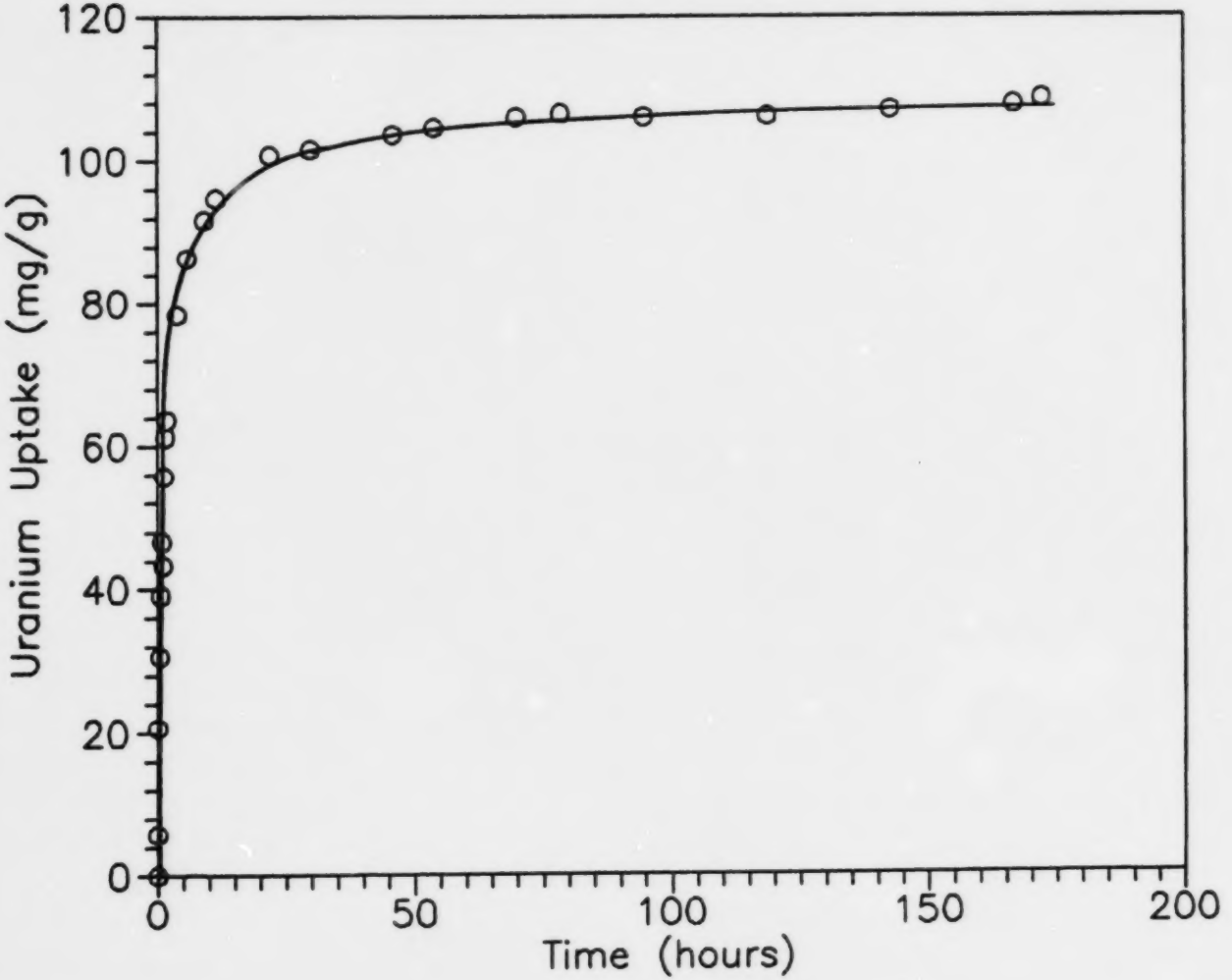

Figure 3 Kinetics of Uranium Uptake on Immobilized Biomass